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THE EFFECTS OF HIGH INTENSITY NOISE ON HUMAN PERFORMANCE

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Foreword

This study was initiated by the Biomedical Laboratory, Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio 45433. The research was conducted by C. S. Harris, Biological Acoustics Branch, Biodynamics and Bionics Division, under Project 7231, "Biomechanics of Aerospace Operations," and Task 723103, "Biological Acoustics in Aerospace Environments." Acknowledgment is made of the assistance provided by Mr. H. C. Sommer and Staff Sergeant W. C. Knobloch of the Biomechanics and Bionics Division. Research covered herein was accomplished in late 1966 and early 1967.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
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The following corrections apply to AMRL-TR-67-119, The Effects of High Intensity Noise on Human Performance.

On page 10, Figures 7 and 8, the illustrations have been reversed although the titles are printed correctly. The graph with abscissa "Noise Conditions" should be Figure 7, and the graph with abscissa "Sessions" should be Figure 8.

Abstract

Four experiments were conducted on the effects of broadband, high intensity noise on human performance. In two experiments the subjects' performance was measured on a Discrimination Task, based primarily upon visual discrimination and short term memory, and in the other two experiments performance was measured on a Hand-Tool Dexterity Test. Four different noise exposure conditions were used in each experiment: control (70 dB), 120 dB, 130 dB, and 140 dB (re 0.0002 dyne/cm^2). In one experiment using the Discrimination Task, the subjects wore earplugs, and in the other, subjects wore earplugs and an earmuff with one earcup to produce an asymmetrical noise exposure at the ears. These two types of ear protectors were worn also by the subjects in the two experiments using the Hand-Tool Dexterity Task. Decrements on the Discrimination Task were obtained at the two highest noise intensities for the asymmetrical exposure, and no decrements were obtained for any symmetrical exposure. With the Hand-Tool Dexterity Test, significant decrements were obtained at the noise levels of 130 dB and 140 dB with symmetrical exposure, and at 140 dB with the asymmetrical exposure. The difference in performance between the two groups was due to a different initial level of ability on the task rather than due to symmetrical versus asymmetrical exposure conditions. The results indicate that asymmetrical exposure had a greater detrimental effect on the Discrimination Task than the symmetrical exposure, while there was no differential effect on the Hand-Tool Dexterity Test. These results are discussed as a possible effect of the action of high intensity noise on the vestibular system.

SECTION I.

Introduction

Various subjective symptoms have been reported by individuals exposed to high intensity jet noise and several explanations have been offered to account for the symptoms. Nausea, vertigo, incoordination, and a general weakness of the body have been suggested as due to vestibular stimulation and to the elicitation of reflexes by vibration of the skin, muscles, and joints (refs 1, 3). Symptoms of mental confusion or difficulty in thinking have also been noted (ref 3).

In spite of the interest in effects of jet noise on men working in such environments very little has been accomplished in the objective measurement of human performance efficiency in noise. Any of the symptoms experienced by individuals in jet noise could lead to a reduction in performance efficiency. Furthermore, since proprioceptive reflexes function for the most part without conscious awareness, performance efficiency could be affected rather severely at noise intensity levels lower than those necessary to elicit subjective reports of dizziness, incoordination, and mental confusion.

In previous studies (refs 4, 6), we have demonstrated that the ability of subjects to balance on narrow rails (equilibrium function) was adversely affected at noise intensity levels below those that elicited the specific subjective symptoms discussed above. A particularly important variable, in addition to noise intensity, in producing decrement on the rail test was an asymmetrical presentation of the noise to the ears, i. e., binaural stimulation of unequal intensities at each of the ears. Using higher intensities of noise other investigators have found asymmetrical exposures to produce more severe subjective symptoms than symmetrical exposures (ref 1).

The present study represents an extension of the study just described that was conducted using the rail test. In this experiment, an attempt was made to determine whether comparable results could be obtained using different types of tasks. One task was a *Discrimination Task* that required primarily the use of visual discrimination and short term memory, and the other task was a *Hand-Tool Dexterity Test* designed " - - to measure manipulative skill independent of intellectual factors" (ref 2). Of particular interest was the determination whether asymmetrical exposure has a more adverse affect on these tasks than symmetrical exposure or whether the observed effect is specific to the rail test. The subjective measure used in the rail test study (ref 4) was also used in the present experiment for correlation with the results of the Mental Task and the Hand-Tool Dexterity Test.

SECTION II.
Method

SUBJECTS

A total of 48 male university students was used as subjects in four experiments. They were paid volunteers and all were in their late teens or early twenties. In addition to normal hearing at audiometric test frequencies from 500 to 6000 Hz, subjects had approximately equal sensitivity in both ears for each test frequency. No subjects were included in the study who had greater than 5 dB (re 0.0002 dyne/cm²) hearing difference between the right and left ear at any frequency.

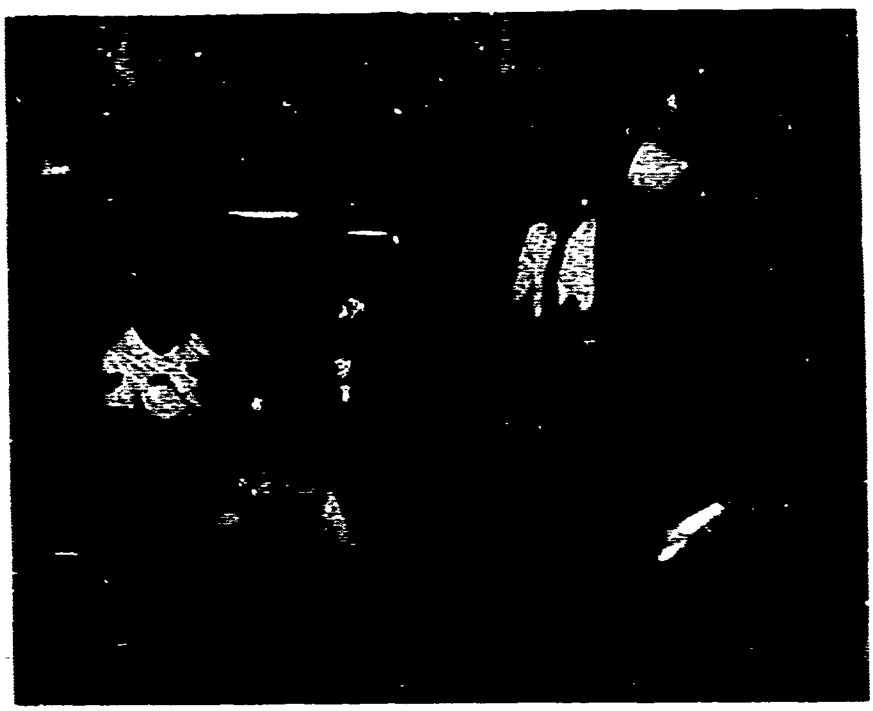

Figure 1. Experimental Arrangement for Subject Testing with Hand-Tool Dexterity Test

NOISE SOURCE AND CHAMBER

Subjects were tested in a large reverberation chamber (14.8 x 17.3 feet) which was vacant except for the experimenter, the subject, the task, and the sound source. Figure 1 shows the location of the subject and experimenter in the noise chamber while the Hand-Tool Dexterity Test was being administered. The subject sat in a sidearm desk while taking the paper and pencil Discrimination Task.

Figure 2 presents the ambient octave band levels of the noise used in the study and the resulting octave band levels of the noise as a consequence of the different types of ear protection provided the subjects. There were two basic exposure conditions presented to the subjects, a symmetrical exposure condition in which the subjects wore earplugs, and an asymmetrical exposure condition in which the subjects wore earplugs in both ears and an earcup covering the right ear.

EXPERIMENTAL MEASURES

Discrimination Task

One page from the Task used in this experiment is presented in figure 3. Symbols appeared in 1-inch square boxes. One box contained six symbols and was centered directly above four boxes each of which also contained six symbols. The subjects' task was to compare each of the four boxes with the one centered above them and to note the number of differences between them on a line directly under each of the four boxes. In each box there was an "X" or a "V" in the upper right hand corner; an "O" or a "/" in the upper left hand corner, with additional pairs of symbols occupying the remaining positions shown in figure 3. The comparison was made as to whether the same or different symbols occupied the same relative spatial position. Under each of the four boxes the subject wrote a number that represented the number of differences between that particular box and the one centered above. The maximum number of differences that could occur was six and the minimum was zero. After completion of a set of comparisons, the subjects went on to the next set of five boxes, then to the next until all were completed or until the time allotted to the task had expired.

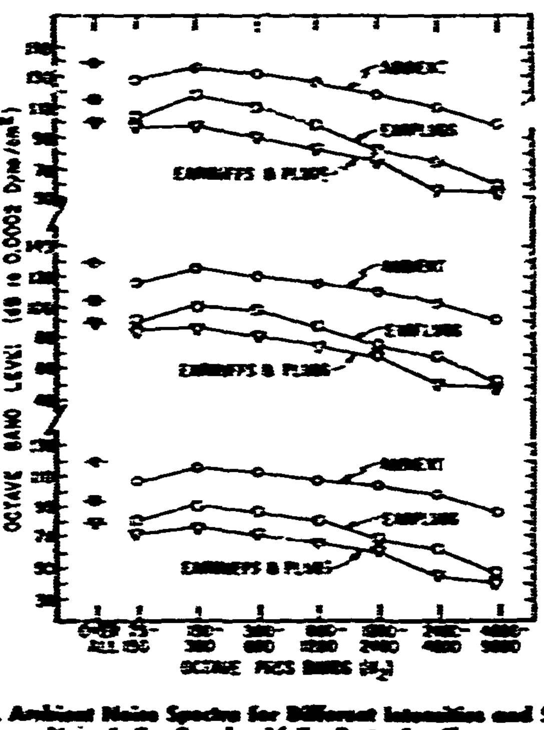

Figure 2. Ambient Noise Spectra for Different Intensities and Spectra of Noise in Ear Canals with Ear Protection Shown

Performance on this task was measured in two 4-minute periods, with 1 minute rest given between periods. Six different booklets were prepared with 14 sheets in each one so that a different test booklet was available for each subject for each testing session. The order of the individual sheets in each booklet was randomly assigned from ten different master sheets. Two scores were obtained for each subject, a score for the first 4 minutes and a score for the second 4 minutes of testing. The score for each of these time periods was the total number of boxes completed minus the number of errors made. None of the subjects were able to complete all of the comparisons within the 4-minute time limit.

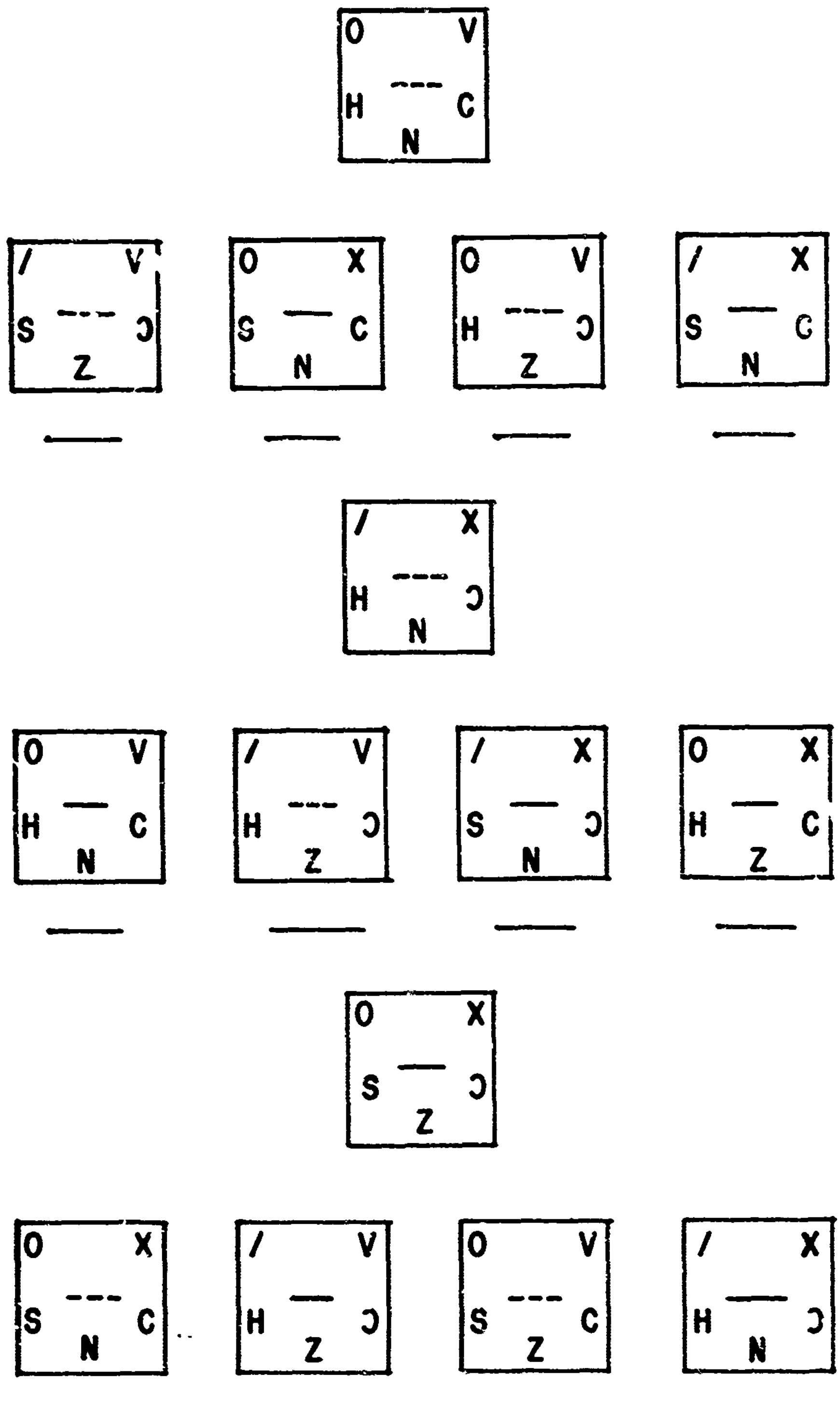

Figure 3. One Page of Discrimination Task Used in Experiments

Hand-Tool Dexterity Test

The equipment for this task consisted of three horizontal rows of nuts and bolts mounted on a wooden stanchion. The nuts and bolts were of three different sizes and four of the same sizes were mounted in each row. The Hand-Tool Dexterity Test was developed by Bennett "to provide a measure of proficiency in using ordinary mechanics' tools" (ref 2). The subjects' task was to remove all the bolts from the left upright and transfer them to corresponding rows on the right upright. The instructions and procedure recommended by Bennett (ref 2) were used. A foam rubber pad was placed over the working area surrounding the task to dampen the vibration of the nuts and bolts produced by the high intensity noise. The score on this task was the time taken by the subject to transfer the nuts and bolts from the left upright to the right upright. Although no norms for college students are presented by the author of this task, norms are presented for 4ll male adults at a vocational guidance center. The score corresponding to the 1st percentile was 12 min, 47 sec, to the 50th percentile 6 min, 53 sec, and to the 99th percentile 4 min, 32 sec.

SUBJECTIVE MEASURE

A subjective evaluation of the noise was obtained after each noise exposure. The measure was based on a Semantic Differential technique developed by Osgood et al (ref 7) for measuring meaning. The subjects were asked to rate "My Experience in the Noise Chamber" on 16 scales of "bipolar" adjectives. Four bipolar adjectives were chosen to assess each of four factors. The adjective scales of good-bad, nice-awful, valuable-worthless, and pleasant-unpleasant were used to assess an Evaluative factor (E). The scales of heavy-light, large-small, thick-thin, and strong-weak were used to assess a Potency factor (P). Sharp-dull, angular-rounded, active-passive, and fast-slow were used to assess an Activity factor (A). The scales of awkward-graceful, private-public, exciteable-calm, and constricted-spacious were used to sample what Osgood et al (ref 7) suggest may represent "some sort of anxiety factor" (Anx). Standard instructions were given for the Semantic Differential measure. Since in previous experiments these factors were significantly correlated and a more reliable measure could be obtained by using one score based on all four measures, in this study each subject's score was the mean of his ratings of the 16 bipolar adjectives. Scoring was on a scale from 1-7. A score of 1 would indicate that the subject rated his experience in the noise as good, light, passive, and calm, whereas a score of 7 would indicate that the subject rated his experience as bad, heavy, active, and excitable.

Our hypothesis was that the results obtained with the subjective measure would be similar to the results obtained in our previous study in which the subjective measure was presented after the rail test. In the rail test study, the mean subjective rating increased with the intensity of the noise, and the means for the asymmetrical noise exposure conditions were higher than the means for the symmetrical exposure conditions.

PROCEDURE AND EXPERIMENTAL DESIGN

Upon their first appearance at the laboratory subjects were given instructions and practice in the proper procedure for performing the tasks. The groups that performed the Discrimination Task came for two preliminary training sessions in which they performed the task without noise in the same manner as used in the experiment proper, i.e., two 4-minute testing periods separated by a 1-minute rest period. In addition, at the end of the second preliminary training session subjects were briefly exposed to the noise at each of the intensity levels used in the study. The groups that performed the Hand-Tool Dexterity Test came for one preliminary training session in which they performed the test twice, and at the end of the practice testing were also exposed to the noise at the intensity levels used in the study. Subjects were exposed to the noise during

the practice session to reduce possible anxiety that might arise later in the experiment due to the unaccustomed exposure to noise.

The same experimental design was used in all experiments. Each subject received all experimental conditions at ambient intensity noise levels of control (70 dB), 120 dB, 130 dB, and 140 dB (re 0.0002 dyne/cm²). The four experimental conditions were presented in four different orders, ABCD, BDAC, CADB, and DCBA. Two subjects were assigned to each of the orders of presentation in the experiments with 8 subjects, and 4 were assigned for each order in the experiments with 16 subjects. A summary of the experiments and the various conditions involved in each is given in table I.

TABLE I

SUMMARY TABLE OF EXPERIMENTAL CONDITIONS

Experiment	*No. of Ss*	*Ear Protection*	*Task During Noise*	*After Noise*
I	8	Earplugs	Discrimination Task	Rail* Subjective
II	8	Earplugs and 1 Muff	Discrimination Task	Rail* Subjective
III	16	Earplugs	Hand-Tool	Subjective
IV	16	Earplugs and 1 Muff	Hand-Tool	Subjective

*In these experiments, a rail test for measuring equilibrium was presented immediately upon termination of the noise, and the subjective evaluation of the noise was obtained subsequently. The rail test data have been reported in a previous paper (ref 4).

SECTION III.
Results

The same analysis of variance technique was applied to all data obtained in the experiments, since the same experimental design was used for all experiments. The technique was one recommended by Lindquist (ref 5), for use with a Type II experimental design.

Table II presents the results of Variance Analyses for the data obtained by use of the Discrimination Task. In the four analyses summarized in this table only one significant effect was obtained for noise conditions. This effect was obtained for the first 4-minute testing session for the asymmetrical exposure. Mean differences were evaluated by use of a $\underline{t}$ test. The decrements associated with this significant effect were obtained at 130 dB and 140 dB and they differed from the control measure at probability levels of $p<.10$ and $p<.05$ respectively (see table III). Figure 4 presents these data in graphic form. Although, the absolute difference between any noise condition and the control condition is relatively small, the difference between asymmetrical and symmetrical exposures is clearcut for the first 4-minute period. There is improvement in performance, although not statistically significant, at the 130 dB and 140 dB levels in the symmetrical group and a decrement in performance at these levels for the asymmetrical group. There was also a significant effect for sessions obtained during the first 4-minute test session for the asymmetrical exposure. The mean of the 4th session was significantly larger than the means for sessions 1 and 2.

The results presented above were based on a corrected score measure which was the number of boxes completed minus the number of errors made. Therefore, the decrement in performance could have been due to an increase in the number of errors or due to a decline in the number of

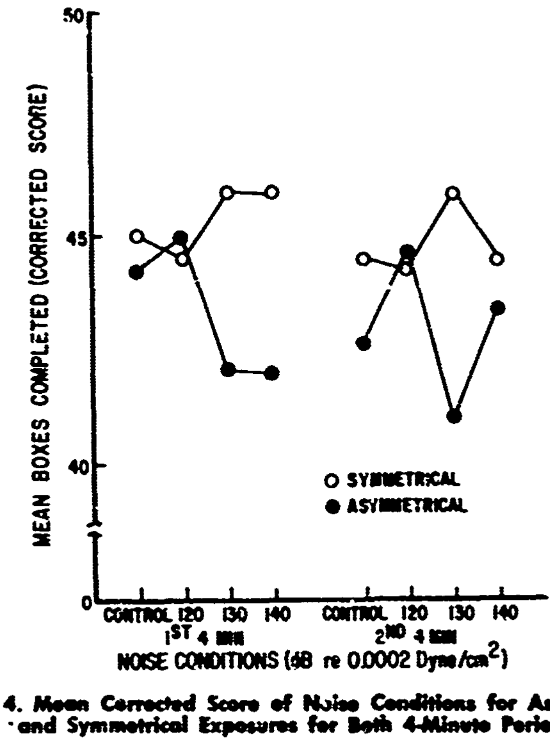

Figure 4. Mean Corrected Score of Noise Conditions for Asymmetrical and Symmetrical Exposures for Both 4-Minute Periods

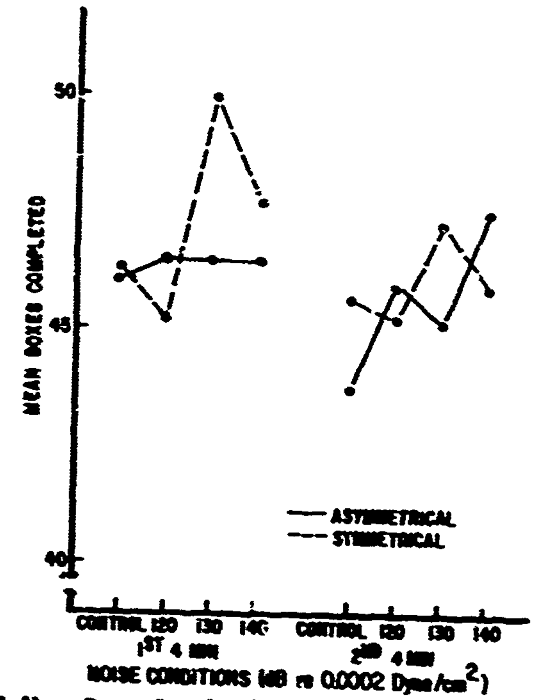

Figure 5. Mean Boxes Completed for Noise Conditions for Asymmetrical and Symmetrical Exposures During Both 4-Minute Periods

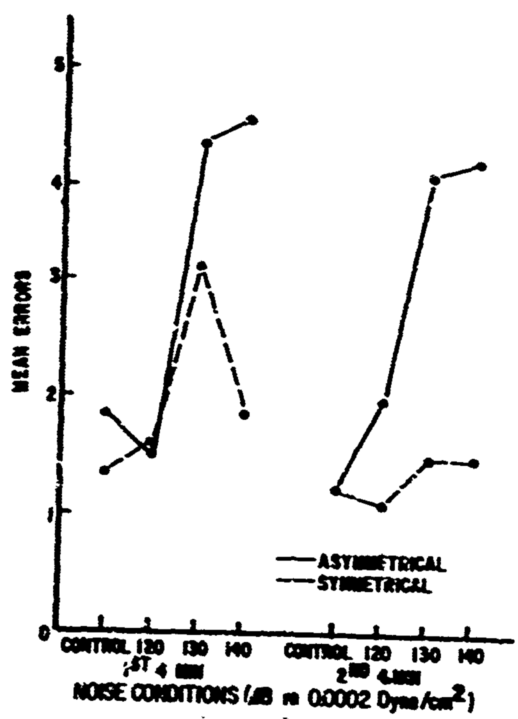

Figure 6. Mean Errors for Noise Conditions for Asymmetrical and Symmetrical Exposures During Both 4-Minute Periods

items attempted. Figures 5 and 6 help to clarify what happened to the subjects' performance as a result of the noise exposures. In figure 5, during the first 4 minutes for the asymmetrical exposure, the subjects completed approximately the same number of boxes under all noise conditions. If the same period is examined in figure 6 for asymmetrical exposure, the mean errors increased with the increasing intensity of the noise exposure. Therefore, the reason for the decrement in performance is obvious.

TABLE II

RESULTS OF VARIANCE ANALYSES FOR CORRECTED SCORE OF DISCRIMINATION TASK

	Source of Variance			
Analysis	*Groups (Order)*	*Noise Conditions*	*Sessions*	*NC x S*
Earplugs and 1 Muff				
1st 4 minutes	n.s.	$p<.05$	$p<.05$	n.s.
2nd 4 minutes	n.s.	n.s.	n.s.	n.s.
Earplugs				
1st 4 minutes	n.s.	n.s.	n.s.	n.s.
2nd 4 minutes	n.s.	n.s.	n.s.	n.s.

TABLE III

MEANS AND DIFFERENCES FOR CORRECTED SCORE OF DISCRIMINATION TASK FOR NOISE CONDITIONS

Noise Conditions	*Mean*	*A*	*B*	*C*	*D*
Earplugs and 1 Muff					
1st 4 Minutes					
A (Control)	44.25		.72	2.13*	2.25**
B (120 dB)	45.00			2.88**	3.00***
C (130 dB)	42.12				.12
D (140 dB)	42.00				

Means for Nonsignificant Measures				
Earplugs and 1 Muff	*Control*	*120 dB*	*130 dB*	*140 db*
2nd 4 Minutes	42.62	44.75	41.00	43.42
Earplugs				
1st 4 Minutes	45.00	44.50	45.88	45.88
2nd 4 Minutes	44.50	44.25	45.88	44.50

*$p<.10$
**$p<.05$
***$p<.01$

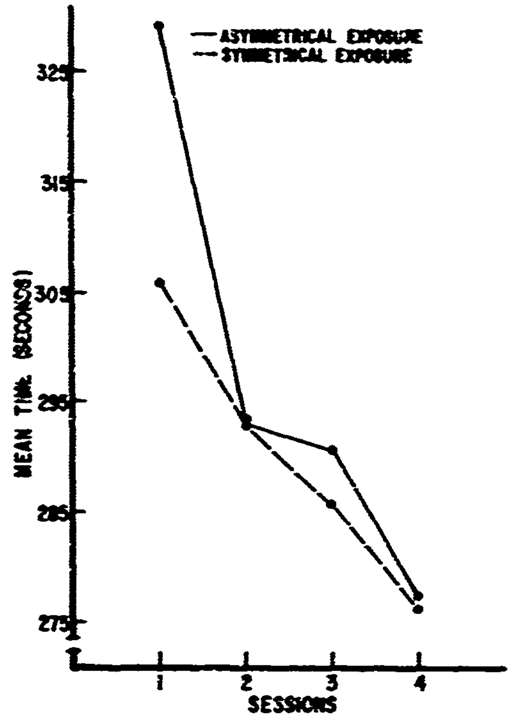

Figure 7. Mean Time to Complete Hand-Tool Dexterity Test at Each Noise Condition for Asymmetrical and Symmetrical Exposures

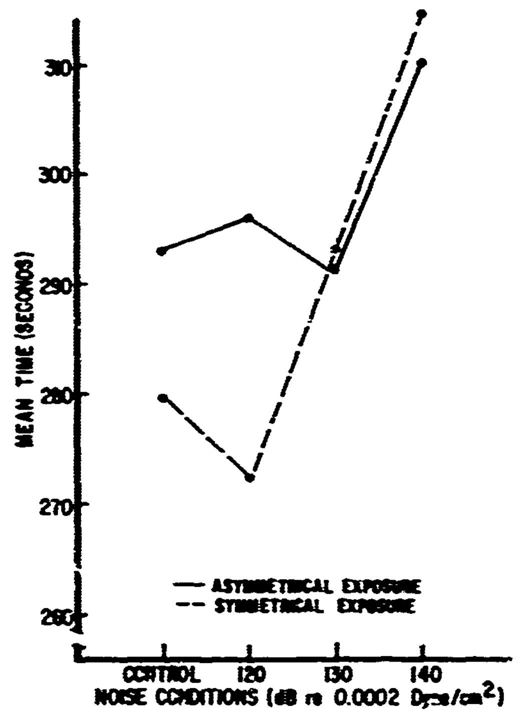

Figure 8. Mean Time to Complete Hand-Tool Dexterity Test at Each Session for Asymmetrical and Symmetrical Exposures

These figures also make it obvious why no significant decrement in performance was obtained during the second 4 minutes for the asymmetrical exposure. As can be seen in figure 6, there is little change in error scores from the first 4 minutes to the second 4 minutes, however, figure 5 reveals that the number of items completed, relative to the control group, increased with noise intensity during the second 4-minute exposure and this increase cancelled out the effect of the errors according to our scoring procedure. By examining the same figures for symmetrical exposures, the mean error is much less at the two higher noise levels than for the asymmetrical exposures. Further, the small increase in error is more than compensated for by an increase in the number of items attempted.

Table IV presents the results of the Analyses of Variance performed on the scores obtained by use of the Hand-Tool Dexterity Test. In the analyses performed for the two exposure groups, significant effects were obtained both for noise conditions and for sessions. Significant increases in the time taken to complete this task occurred at noise levels of 130 dB and 140 dB for symmetrical exposures, and at the noise level of 140 dB for asymmetrical exposures (see table V). Figure 7 presents the mean time in seconds that the subjects took to complete the task in both exposure groups at each noise condition. From this figure there was a large difference between the control means for these groups. This large difference in the initial ability of these groups on the task makes it difficult to determine the relative effects of asymmetrical versus symmetrical exposure. The difference between groups was due mainly to the data obtained in session 1 as seen in figure 8 where mean time to complete the task is plotted against sessions for both symmetrical and asymmetrical exposures. There was a large difference between these groups during session 1, but relatively little differences between groups during the remaining three sessions. Because of the extremely poor performance of the subjects during session 1 for asymmetrical ex-

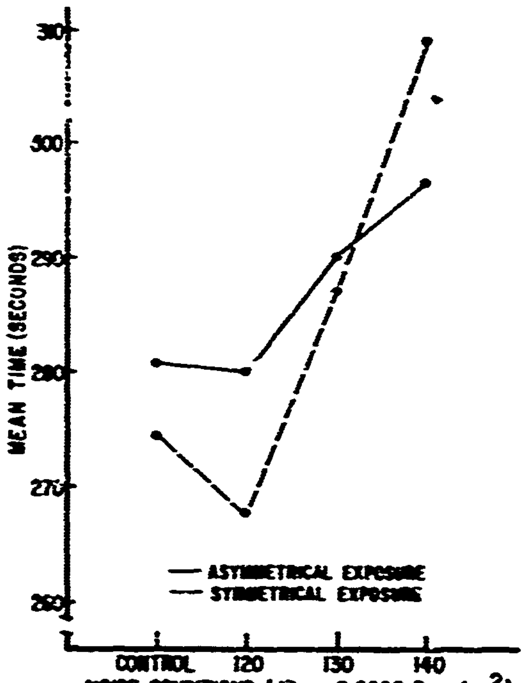

Figure 9. Mean Time to Complete Hand-Tool Dexterity Test at Each Noise Condition for Asymmetrical and Symmetrical Exposures with Session 1 Data Excluded

posure regardless of noise intensity level, differences between noise conditions were obscured. Performance at the lower noise levels was so poor that the subjects could not show much increase in mean performance time at the higher noise levels where an increase might be expected. This was indeed the case as seen in figure 9 where the same data are plotted as in figure 7 minus the data for session 1. With the data from session 1 removed, the shape of the curve for symmetrical exposures remains approximately the same as with all data included. In contrast, the

TABLE IV

RESULTS OF VARIANCE ANALYSES FOR HAND-TOOL DEXTERITY TEST (TIME SCORES)

Analysis	*Source of Variance*			
	Groups (Order)	*Noise Conditions*	*Sessions*	*NC x S*
Earplugs and 1 Muff	n.s.	p<.005	p<.001	n.s.
Earplugs	n.s.	p<.001	p<.001	n.s.

TABLE V

MEANS AND MEAN DIFFERENCES FOR NOISE CONDITIONS FOR HAND-TOOL DEXTERITY TEST (TIME SCORES IN SECONDS)

Noise Conditions	*Mean*	A	B	C	D
Earplugs and 1 Muff					
A (Control)	293.25		2.94	1.81	17.00*
B (120 dB)	296.19			4.75	14.07*
C (130 dB)	291.44				18.81*
D (140 db)	310.25				
Earplugs					
A (Control)	279.69		7.13	13.69**	35.25*
B (120 dB)	272.56			20.82*	42.38*
C (130 db)	293.38				21.66*
D (140 db)	314.94				

*p<.01
**p<.02

curve for asymmetrical exposure shows a large relative increase in the mean time to complete the task at the 130 dB level. This comparison brings the results of both groups into agreement; an increase in the mean time to complete the task at 130 dB and 140 dB over the mean time for control and 120 dB. The differences among noise levels are still larger for the symmetrical exposure group than for the asymmetrical exposure group and may represent a true difference between groups.

In the experiment with the Hand-Tool Dexterity Test, three subjects mentioned that they were bothered by the shaking of the smallest bolts in their stations by the noise at 140 dB. The

shaking occurred when as part of the standardized test procedure the subjects transferred the smallest nuts and bolts to the opposite side, tightened with the fingers, and then tightened further using a screwdriver and an adjustable wrench. The main difficulty occurred in getting the screwdriver and wrench in place after they had initially tightened the nuts and bolts with their fingers. Direct observations by the experimenter indicated that shaking of the nuts and bolts did add to the time required to complete the task but only by a few seconds at most. Eleven subjects, questioned after the spontaneous comments of the other three had been received, reported that the shaking of the nuts and bolts bothered them very little and they thought it had little effect on their performance.

The Semantic Differential measure indicated that asymmetrical exposure was rated a more severe subjective experience than the symmetrical exposure condition when the Discrimination Task was used. However, when the Hand-Tool Dexterity Task was used, there was little difference in the subjective ratings for the symmetrical and asymmetrical groups (see tables and VII). In figure 10, there was a clear difference between mean subjective ratings for the asym-

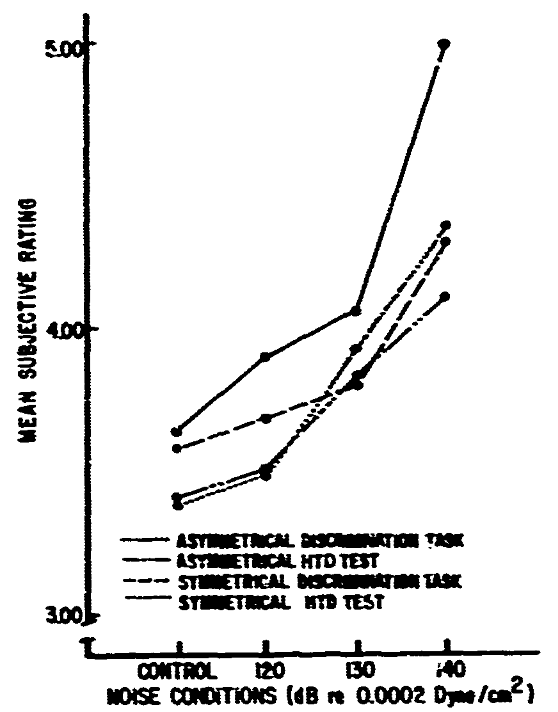

Figure 10. Mean Subjective Rating at Each Noise Condition for All Experiments

metrical and symmetrical exposures when the Discrimination Task was used. These data indicate that this was the case, since a significant effect for noise conditions was obtained in analyses of variance for only the asymmetrical exposure. On the other hand, the symmetrical exposure would seem to be more severe at the higher noise levels than asymmetrical exposure for the Hand-Tool Dexterity Test, if we judge from the curves in the figure. However, statistical analyses conducted on these data indicate that this difference was probably not a genuine difference (see tables V and VI) since for both groups the mean rating at 130 dB and 140 dB were both significantly higher than the mean ratings at control and 120 dB, and the mean rating at 140 dB was significantly greater than the mean rating at 130 dB.

TABLE VI

RESULTS OF VARIANCE ANALYSES FOR SUBJECTIVE RATINGS

	Source of Variance			
Analysis	*Groups (Order)*	*Noise Conditions*	*Sessions*	*NC x S*
Mental Task				
Earplugs and 1 Muff	n.s.	$p < .005$	n.s.	n.s.
Earplugs	n.s.	n.s.	n.s.	n.s.
Hand-Tool Dexterity Test				
Earplugs and 1 Muff	n.s.	$p < .001$	n.s.	n.s.
Earplugs	n.s.	$p < .001$	n.s.	n.s.

TABLE VII

MEANS AND MEAN DIFFERENCES FOR SUBJECTIVE RATINGS AT EACH NOISE CONDITION IN ALL EXPERIMENTS

Noise Conditions	*Mean*	*A*	*B*	*C*	*D*
During Mental Task					
Earplugs and 1 Muff					
A (Control)	3.67		.24	.39	1.32**
B (120 dB)	3.91			.15	1.08**
C (130 dB)	4.06				.93**
D (140 dB)	4.99				
Means for Nonsignificant Measure					
Earplugs		3.60	3.71	3.84	4.31
During Hand-Tool Dexterity Test					
Earplugs and 1 Muff					
A (Control)	3.41		.10	.46**	.72**
B (120 dB)	3.51			.36**	.62**
C (130 dB)	3.87				.26*
D (140 dB)	4.13				
Earplugs					
A (Control)	3.37		.12	.58**	1.01**
B (120 dB)	3.49			.46*	.89**
C (130 dB)	3.95				.43*
D (140 dB)	4.38				

*$p < .05$
**$p < .01$

Discussion

The results obtained with the Discrimination Task are relatively clearcut if only the data based on the corrected scores are considered. Asymmetrical noise exposure had a detrimental effect on the task during the first 4 minutes of exposure but no detrimental effect during the second 4-minute exposure session. Furthermore, symmetrical noise exposure had no significant effect on the Discrimination Task during either the first or second 4-minute periods.

The results presented above were based on a corrected score measure that was the number of boxes completed minus the number of errors made. Therefore, the decrement in performance could have been due to an increase in the number of errors or a decline in the number of items attempted. The differences between asymmetrical and symmetrical exposures can be better understood by considering the number of boxes completed and the number of errors rather than the corrected score. The most interesting aspect is the difference in the number of errors made by the two groups. The asymmetrical exposure at 130 dB and 140 dB not only produced more errors, but the mean error for the second 4 minutes was almost as large as it was for the first 4 minutes. This was clearly not the case for symmetrical exposures. The number of errors in the latter case showed a clear decline from the first 4-minute period to the second 4-minute period.

The apparent adaptation of the asymmetrical group to the noise occurred by an increase in the number of items attempted and not by a decrease in the number of errors made. The adaptation of the symmetrical group to the noise was due to a decrease in the number of boxes attempted with a corresponding increase in accuracy (fewer errors).

In contrast to the results obtained on the Discrimination Task, the results of the Manual Dexterity Task do not support a differential effect for asymmetrical versus symmetrical exposures. A significant decrement in performance was obtained in the symmetrical exposure group at 130 dB and 140 dB, and at 140 dB for the asymmetrical exposure group. This result was somewhat surprising since a previous study using a rail test (ref 4), as well as the Discrimination Task in this study proved that these tasks were more adversely affected by asymmetrical exposures.

The greatest difference between the Hand-Tool Dexterity Test groups occurred during session 1, where the asymmetrical exposure group did much worse than the symmetrical exposure group. The two groups were quite similar in performance scores during the last three testing sessions. When only the data of the last three sessions were used to compute the means for noise conditions (figure 8), it was found that the curves had approximately the same pattern; larger mean times to complete the task at the higher noise intensity levels of 130 dB and 140 dB than were obtained at the lower levels of control and 120 dB. Therefore, we would tentatively conclude that if subjects of comparable initial ability had been used a significant increase in the time taken to complete the task would have occurred at the higher noise intensity levels for both symmetrical and asymmetrical exposures.

There are a number of possible reasons for the failure to demonstrate a differential effect for asymmetrical-symmetrical exposures. One possibility is that the adverse effect on performance for both asymmetrical and symmetrical exposures was due to a direct mechanical interference with this task and this mechanical interference was sufficient to obscure a differential effect. As mentioned in the results section, three subjects stated that they were bothered by shaking of the smallest bolts in their stations at the higher noise intensity level of 140 dB. Mechanical interference undoubtedly did slow down the subjects at 140 dB, even though most subjects reported that shaking of the bolts acted to slow them down very little. However, mechanical interference probably did not produce the decrement at 130 dB.

Considering the data obtained in previous studies on the rail task, and in the present study on the Discrimination Task and the Hand-Tool Dexterity Task, the more adverse effects may be expected with asymmetrical exposure on tasks that require a high degree of control over bodily balance and tasks that require visual discrimination and short term memory. However, on simple manual dexterity tasks there would seem to be little difference in the effects of asymmetrical versus symmetrical exposures. Additional experiments should be conducted using subjects with the same initial ability on manual dexterity tasks to determine the influence of this variable.

The overall results seem clear in pointing out that the rated severity of noise exposure is very much affected by the activity an individual is engaged in when presented the noise. The data obtained by use of the subjective measure agree well with the results of the rail test and the Discrimination Task in that asymmetrical exposures were rated as being more severe than symmetrical exposures. In addition, if the difference on the Hand-Tool Dexterity Test was due to the difference in the initial level of ability of the groups on this task rather than to the symmetrical-asymmetrical variable, then the subjective measure also agrees with the results of this task, since subjective ratings indicate essentially no difference in results as a consequence of symmetry-asymmetry.

The results of the present study and the previous one using the rail test are unusually clear-cut since most of the literature on the effects of noise on human performance point out the confused state of the area. Shoenberger and Harris (ref 9) state: "Perhaps the only conclusion one can reach from reading reviews of the effects of noise on human performance is that there are effects. Whether these effects are detrimental or facilitative (or both), how they are related to intensity, what changes occur over time, etc, remain largely undetermined." The main reason our results seem clearcut relative to the previous literature is that we are no longer studying the same problem as is discussed in some of the early review articles on the effects of noise on performance. Although the noise intensities in the ear canals of our subjects were no higher than have been used in many previous experiments reported in the literature, the difference appears to be greater extra-auditory effects of noise on other body mechanisms in the present studies. The exact extra-auditory system that interacts with noise in the ear canal to produce decrements in performance is not known at this time. Ades (ref 1) has suggested a number of years ago that "the first sensory system after the auditory to be assaulted by intense noise is the vestibular." Our results give some support to this premise since those tests that involved greater proprioceptive activity (the rail test and Hand-Tool Dexterity Test) revealed greater sensitivity to the noise than did the test that involved little proprioceptive activity (Discrimination Task). Many other explanations of the results of the preesnt experiment could be offered, however additional research is needed to better define the response of the vestibular system to high intensity noise exposure.

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13. ABSTRACT

Four experiments were conducted on the effects of broadband, high intensity noise on human performance. In two experiments the subjects' performance was measured on a Discrimination Task, based primarily upon visual discrimination and short term memory, and in the other two experiments performance was measured on a Hand-Tool Dexterity Test. Four different noise exposure conditions were used in each experiment: control (70 dB), 120 dB, 130 dB, and 140 dB (re 0.0002 dyne/cm^2). In one experiment using the Discrimination Task, the subjects wore earplugs, and in the other, subjects wore earplugs and an earmuff with one earcup to produce an asymmetrical noise exposure at the ears. These two types of ear protectors were worn also by the subjects in the two experiments using the Hand-Tool Dexterity Task. Decrements on the Discrimination Task were obtained at the two highest noise intensities for the asymmetrical exposure, and no decrements were obtained for any symmetrical exposure. With the Hand-Tool Dexterity Test, significant decrements were obtained at the noise levels of 130 dB and 140 dB with symmetrical exposure, and at 140 dB with the asymmetrical exposure. The difference in performance between the two groups was due to a different initial level of ability on the task rather than due to symmetrical versus asymmetrical exposure conditions. The results indicate that asymmetrical exposure had a greater detrimental effect on the Discrimination Task than the symmetrical exposure, while there was no differential effect on the Hand-Tool Dexterity Test. These results are discussed as a possible effect of the action of high intensity noise on the vestibular system.

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